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$$FP = \cos FPP_0 \cdot P_0P = \cos \frac{x+x_0}{2} \cdot P_0P < \cos x_0 P_0P < \cos x_0 (x-x_0).$$

$\therefore \cos x \cdot (x-x_0) < \sin x - \sin x_0 < \cos x_0 (x-x_0)$, which is (10).

The outer part of Fig. 5 can also be used to prove that

$$\sin x - \sin x_0 = 2 \cos \frac{x+x_0}{2} \sin \frac{x-x_0}{2}.$$

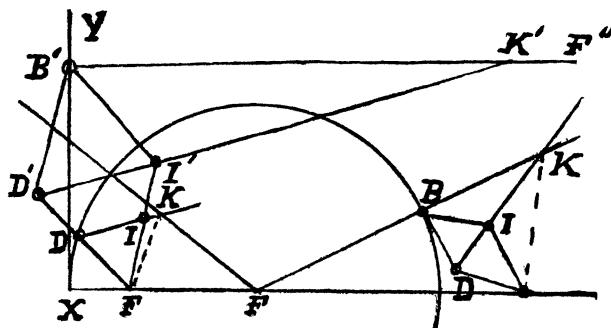
A LINKAGE FOR DESCRIBING THE CONIC SECTIONS BY CONTINUOUS MOTION.

By JOHN JAMES QUINN, Ph. B., Head of the Department of Mathematics and Manual Training, Warren High School, Warren, Pa.

The linkage is a material embodiment of the facts and conditions set forth in the following

THEOREM: *If one vertex of a movably pivoted rhombus is constrained to move in the circumference of a directing circle, while the opposite vertex is fixed in the diameter (or diameter produced), the locus of the intersection of the diagonal (produced) through the other two vertices with the radius of the directing circle is a conic.*

Let $BIDF$ be the rhombus with the vertex B moving in the circumference



of the directing circle whose center is F' ; F' the opposite vertex fixed within (without) the diameter; and DI the diagonal produced to intersect the radius (produced) in the point K . Draw KF , and FK' . Then in the figure to the left,

$$FK + KF' = BK + KF' = BF' = \text{constant.} \quad \therefore \text{The locus of } K \text{ is an ellipse.}$$

In the figure to the right,

$$F'K - FK = F'K - BK = BF' = \text{constant.} \quad \therefore \text{The locus of } K \text{ is an hyperbola.}$$

Now suppose that the radius of the directing circle becomes infinite. Then the circumference becomes the line XY , perpendicular to the diameter (the directrix); BF becomes the line $B'F'$, parallel to the diameter, and the diagonal $D'I$ intersects it in K' .

Hence $B'K' = FK'$. $\therefore$ The locus of K' is a parabola.

COROLLARY 1. *The diagonal of the rhombus is a tangent to the curve in every position; and the second diagonal is parallel to the normal.*

COROLLARY 2. *When the diagonal is parallel to the radius it is an asymptote.*

COROLLARY 3. *If a point in one side of a movably pivoted rhombus, at a given distance from the vertex, is constrained to move in the circumference of a directing circle, and a point in the adjacent side equidistant from the same vertex is fixed in the diameter (or diameter produced), the locus of the intersection of the diagonal (produced if necessary) through the other two vertices with the radius (or radius produced) of the directing circle is a conic.*

COROLLARY 4. *A conic is the locus of a point which moves so that the ratio of its distances from a fixed circle and a fixed point in its diameter (or diameter produced) is equal to unity.*

The linkage is very easily constructed by using thin strips of wood or metal for each line in the above figure except the diameter of the directing circle, which should be strong enough to support the rest of the linkage without bending. The links representing the diagonal and the radius should be slotted, then there will be an opening at their intersection in which a pencil can be inserted to describe the curve.

The points F and F' represent the foci, one of which, the point F , should be made to slide along the diameter. Then a change in the curve due to a change in the relative position of the foci is made evident.

If the diagonal DI passes through the point F' , and an extra link DE is attached to the vertex D with the point E in the diameter, but so situated that $DE = EF'$, then the vertex I will describe a straight line.

For we have $F'D \times F'I = \text{constant}$. Consequently, if the vertex D describes a circle, the point I must describe its inverse.

The extreme simplicity of this linkage reduces the geometry of the conics to that of the rhombus and the circle.

DEPARTMENTS.

SOLUTIONS OF PROBLEMS.

ALGEBRA.

Problem 185 was also solved by A. H. Holmes, Brunswick, Maine.

187. Proposed by L. E. DICKSON, Ph. D., Assistant Professor of Mathematics, The University of Chicago.

Express by radicals the roots of $x^7 + px^5 + \frac{2}{7}p^2x^3 + \frac{1}{49}p^3x + r = 0$.